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Mechanical Systems, Structures and Materials (MSSM)

Technical Evaluation Report

Otto Sensburg
DaimlerChrysler Aerospace AG
Military Aircraft MT2, Postfach 80 11 60
81663 Munich, Germany

Introduction:

Active Control Technology (ACT) was introduced in the seventies together with fly by wire and Control Configured Vehicle (CCV)-Technology [1].

Several technologies that are now available and widely used for aircraft are:

- Artificial longitudinal and lateral stability
- Manoeuver load control
- Vibration suppression (-leading to flutter suppression)
- Gust load Alleviation

The advent of smart adaptive structures, where distributed control with distributed actuators is applied even further increased the usage of ACT.

The RTO-meeting in Brunswick, Germany from May 8-11, 2000 gave an overview of existing and new technologies.

Hr. Lubert, Daimler Chrysler acted as chairman for the Symposium on **Mechanical Systems, Structures and Materials (MSSM)**.

The Symposium was structured into four sessions, namely:

Session 1: Smart Structures Applications

Session 2: Active Control Technology for Load Alleviation

Session 3: Active Elements for Structural Design

Session 4: Active Materials and Applications

These sessions were thoughtfully chaired by Messrs. P-M. Hutin, ONERA, France, H. Hoenlinger, DLR Germany, W. Lubert, DaimlerChrysler, Germany, D.G. Zimcik, NRC, Canada respectively.

Two keynote speakers have given a very good approach to the way things should be done.

Ed Pendleton from the Air Force Research Laboratory (AFRL), Dayton, Ohio, US presented a concept where he uses the elastic deflections to his advantage similar to

the Wright Brothers in his paper: “How Aeroelastic Wings are a Return to the Past and a Gateway to the Future”

Though wing flexibility was a key to control during the first successful manned powered flight, wing flexibility affected other early designs adversely. Perhaps, the first designer to be affected was Dr. Langley. The unfortunate wing failure that wrecked his machine in 1903 was likely due to wing torsional divergence. The success of the Wright Brothers and the failure of the Langley monoplane provided one of the original reasons for early designer preference for biplanes.

By the mid-1930s, the quest for higher performance and speed led designers to promote monoplanes designs with semi-monocoque structures. As these designs were built and flown, aircraft encountered a wide variety of problems, which we now classify as aeroelastic problems. Wing flutter, wing divergence, buffeting, control effectiveness, and control reversal are examples of aeroelastic problems that have plagued aircraft designs ever since.

Today, aircraft lifting surfaces are designed to be strong enough to meet loading requirements and material is added to provide stiffness adequate to keep them free from flutter, divergence, and buckling. And as pilots and passengers on aircraft, we are glad this is so.

But this added stiffness usually means adding structural weight, so design trades are made between weight and aerodynamic performance for a given set of aerodynamic requirements. As speeds increase, designers often have opted to reduce wing span, increase wing thickness and live with the subsequent reduced aerodynamic performance in an attempt to save weight.

Wing flexibility used as a benefit... The first step towards a new era in aeronautics?

As we enter the second one hundred years of aeronautics development, we are poised to enter a potentially new era in aircraft design. To take full advantage of this, it will take vision and new aircraft materials and new ways of integrating wing design with adaptive control strategies to take advantage of it.

The AFRL Air Vehicles Directorate and NASA have taken a first step by developing a novel technology that offers weight competitive wing designs and improved aerodynamic performance. It is called the Active Aeroelastic Wing or AAW. AAW

Technology is a synergistic technology that integrates air vehicle aerodynamics, active controls, and structures together to maximize air vehicle performance. The concept turns wing aeroelastic flexibility into a net benefit by usage of multiple leading and trailing edge control surfaces activated by a digital flight control system. AAW techniques employ the energy of the air stream to achieve this desirable wing twist with very little control surface motion. The wing then creates the needed control forces with outstanding effectiveness. At higher dynamic pressures, AAW control surfaces are used as "aerodynamic tabs" that promote wing twist for added control force capability instead of trying to overcome control surface losses due to wing elastic twist. At these high dynamic pressures, large amounts of control power can be generated using this approach. In the same design the AAW control can minimize drag at low wing strain conditions and/or minimize structural loads at high wing strain conditions. The AAW concept was first successfully demonstrated by an Air Force / NASA / Rockwell North American team in a transonic dynamics wind tunnel. Now, another joint Air Force /NASA/Boeing team is preparing to take it to flight in California at NASA Dryden.

A similar concept was also presented by Vicky Tischler [2] at the 41st AIAA SDM meeting in Atlanta,GA, USA on 3-6.April 2000 using a fin which was made divergent by aeroelastic tailoring and therefore has higher efficiency than the rigid one. Weight, cost and signature savings can be realized in the order of 20 – 30%.

The MEMS approach of Chih-Ming Ho, US presented in his keynote paper: "MEMS Application to Active Control" is doing things differently by applying small actuators on delta wing tips to influence the vortices coming off that wing and that way controlling the aircraft motion. Again the controlling force comes from the surface not the control. It has to be checked whether such an approach is possible for a full size aircraft or if it just works for the small flying demonstration model shown.

Now the papers presented at the meeting will be reviewed separately:

The acoustic control with piezos of structural vibration (paper 2) is feasible but more research on control laws and applicability has to be done before it can be introduced in to practical designs, "Active Structural Acoustic Control as an Approach for

Acoustic Optimisation of Light Weight Structures” by D. Mayer, B. Vogl, H. Hanselka, Otto von Guericke University Magdeburg, Germany

The adaptive wind tunnel model proposed by L.F. Campanile, V. Carli, D. Sachau, DLR Brunswick, Germany (paper 4) and the smart wing model of Northrop, presented in paper 7 are similar in design and can do the job of otherwise very costly wind tunnel variants.

In paper 6, “Realization of a Shapevariable Fowler Flap on Transport Aircraft” by C. Anhalt, E. Breitbach, D. Sachau, DLR, Germany an intelligent concept for an Airbus A330/340 fowler flap is shown which improves the high lift behavior.

In paper 7, “Active Control Technology at NASA Langley Research Center” was presented by R.R. Antcliff and Anna-Maria McGowan NASA Langley, USA, giving an excellent overview of NASA activities in this field.

Paper 8, “Finite Element Approach for the Design of Control Algorithms for Vertical Fin Buffeting using Strain Actuation” by F. Nitzsche, S. Liberatore, D.G. Zimcik, National Research Council, Canada and paper 11, “Active Fin-Buffering Alleviation for Fighter Aircraft” by J.K. Duerr, U. Herold-Schmidt, J. Becker, Daimler Chrysler Aerospace, Germany showed approaches for fin buffeting alleviation. Their tests have been performed on the ground. In order to assess useable amplitude or strain reductions from active controls the damping coming from unsteady aerodynamic forces in flight must be considered. It seems that a solution using the rudder for low frequencies and strain actuators for high frequencies would be viable.

Cost effectiveness has to be investigated as well as software integration cost, maintainability, reparability etc.

A very interesting study was presented in paper 9, “Active Flutter Suppression using ASTROS with Smart Structures and ASE models” by P.C. Chen, C. Nam, Zona Technology D.D. Liu Arizona State University, US. This is an approach for the future.

Paper 12, “Development of Analysis Tools for Active Shape and Vibration Control” by A. DeBoer, R. Veul, P.Arendsen, NLR, Netherlands gave an overview of analysis tools available at NLR.

Some interesting issues were investigated in paper 13, “Active Control of Buffet Induced Vibrations: Reliability, Maintainability and Robustness Issues” by S. Hanagud, M. Bayon de Noyer Georgia Institute of Technology, D. Henderson, Air Force Research Laboratory, WPAFB, Ohio, US.

An application of Magneto Rheologic Fluids was presented in paper 15, "Design and Fabrication of Semi-Active MR Fluid Based Engine Mount" by R. Ay, M.F. Golnaraghi, A. Khajepour, University of Waterloo, Canada for an engine mount which would allow to adjust the damping.

The problem of optimizing a passive shock absorber for a landing gear was addressed in paper 16, "Optimization of the Passive Shock Absorber of a Military Aircraft" by B. Uhrmeister, DLR, Germany.

A new actuator device was investigated in paper 18, "Active Materials Research at UCLA" by G.P. Carman, University of California, US. If it fulfills what it is promising it would enhance the application of smart structures tremendously.

The problem of applying adaptronics to Helicopter rotor blades was presented in paper 19, "Adaptive Rotor Blade Concepts Direct Twist and Camber Variation" by A. Blueter, U. C. Ehler, D. Sachau, E. Breitbach, DLR, Germany

After all the papers were presented, W. Luber, DaimlerChrysler chaired a round table discussion with the following table participants:

W. Luber, GE

O. Sensburg, GE

D. D.Liu, US

E. Pendleton, Us

D. Zimcik, CA

P-M. Hutin, FR

H. Ottens, NE

After a lively discussion it was concluded that the lack of an actuator which fits all the requirements is impeding the progress. Also more analytical work must be done to bring together Multi Disciplinary Optimization, composite structures and smart materials.

References:

- [1] O. Sensburg, H. Zimmermann

Impact of Active Control on Structures Design

AGARD Multi – Panel Symposium, Fighter Aircraft Design

Florence, Italy 3.-6- October 1977

- [2] V.A. Tischler and V.B. Venkayya,
Airforce Research Laboratory,
Air Vehicles Directorate
Wright Patterson Airforce Base, OH
and Otto Sensburg
DaimlerChrysler Aerospace
Munich, Germany

Aeroelastic Tailoring of Empennage Structures

41st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and
Materials
Conference
Atlanta, GA USA, 3-6 April 2000